CHAPTER 5

SITE CHARACTERIZATION

5-1. General. This chapter discusses the investigation procedures that can be employed if the contamination at the UST is more widespread than the immediate tank area. Typically these procedures are above and beyond what is required during a UST removal. These activities, if required, should be performed under a separate contract from the UST removal so as not to slow down the tank removal process yet avoid potential UST-removal contractor delays. This chapter is included for guidance and completeness of this manual. Additional guidance on site characterization may be found in EM 200-1-3 and ASTM Standard Guides D 5730 and E 1912.

5-2. Subsurface Soil Gas Survey. Soil gas surveys (also called field hydrocarbon vapor tests) are a proven quick and economical in situ field method for determining the presence of subsurface chemical contamination. The soil-gas survey measures the relative concentration of volatile hydrocarbon components in the vadose zone of the soil. Data obtained from these surveys can be used to measure the relative magnitude of volatile hydrocarbons in the soil and contaminant dispersion or migration trends. Quantitation is accomplished with a gas chromatograph.

This information may help determine the need for quantitative soil sampling and/or the need for monitoring well installation. Two basic types of soil-gas surveys commonly performed during UST site assessments are discussed below.

a. Active soil gas survey. The first type is the active soil-gas survey in which a probe is inserted into the subsurface and a volume of soil gas is pumped out of the vadose zone into a sample collection device for analysis. The gas samples are injected into a gas chromatograph that has been calibrated with one or more of the analytes thought to be present onsite.

b. Passive Soil Gas Survey. The second type is the passive soil-gas survey in which a collection device is placed in the subsurface or on the surface of the ground, allowing the atmosphere within the device to come into compositional equilibrium with the soil atmosphere.

c. Comparison of Methods. Active soil-gas surveys can be completed in as little as one day and are most commonly used. Passive soil-gas surveys take several days or weeks to complete. While both methods of soil gas sampling are applicable to sites contaminated by volatile organic compounds (VOCs), passive soil gas sampling may also identify some semivolatile organic compounds (SVOCs)(EPA/510/B-97/001). Detailed guidance on typical soil-gas monitoring may be found in ASTM D 5314.

Soil gas sampling methods also include headspace measurements and flux chamber measurements (EPA/600/8-87/036). Headspace sampling involves placing samples of site soils into a sealed container and measuring the concentrations of organics in the air above the soil (in the headspace) after some equilization period. Flux chamber measurements are obtained by placing an open-bottomed chamber on the soil surface and slowly passing a carrier gas over the soil surface and collecting a sample of the air from the chamber for analysis.

a. Theory. The presence of VOCs in shallow soil-gas indicates the observed compounds may either be in the vadose zone near the probe or in groundwater below the probe. The soil gas technology is most effective in mapping low molecular weight halogenated solvent chemicals and petroleum hydrocarbons possessing high vapor pressures and low aqueous solubilities. These compounds readily partition out of the groundwater and into the soil as a result of their high gas/liquid partitioning coefficients. Once in the soil gas, VOCs diffuse vertically and horizontally through the soil to the ground surface where they dissipate into the atmosphere. The contamination acts as a source, and the aboveground atmosphere acts as a sink, and typically a concentration gradient develops between the two. The concentration gradient in soil gas between the source and ground surface may be locally distorted by hydrologic and geologic conditions (e.g., clays, perched water). However, soil gas mapping generally remains effective because distribution of the contamination is usually broader in areal extent than the local geologic barriers and is defined using a large database. The presence of geologic obstructions on a small scale tends to create anomalies in the soil-gas– groundwater correlation but generally does not obscure the broader areal picture of the contaminant distribution. A soil-gas survey may be performed in the vicinity of each UST. Typically 5 to 10 ground probes are driven to depths similar to that of the bottom of the UST or passive samples are placed around the UST location.

b. Limitations. Soil-gas methods do have limitations, as discussed below:

(1) Soil probing is more difficult if the UST is under a large concrete pad.

(2) A positive result indicating site impacts are present in the soil which could be related to contamination from other nearby sources or from a recent spill.

(3) A positive result could occur (indicating soil contamination when none exists at the location) if volatile hydrocarbons from another source are migrating with and being released from the groundwater.

(4) Plant matter can cause false positive results.

(5) A false negative result, incorrectly indicating that the tank has not leaked, may result if the UST leaked many years ago and the volatile contaminants have largely degraded or dissipated or if the leak involved nonvolatile liquids.

(6) Active soil gas may yield a false negative if rainfall or snowmelt occurs just prior to the sampling. The infiltrating water can drive contaminant vapors ahead of the infiltration front and draw clean atmospheric air into the zone to be sampled.

(7) Headspace methods may not yield samples representative of in-situ vadose zone atmospheres. Large percentages of vapor phase and moderate percentages of solute and sorbed phase contaminants can be lost in the act of soil sampling.

(8) Driven probes tend to degrade natural soil permeability around the body of the probe due to soil compaction concurrent with insertion. This can be a severe limitation to active soil gas extraction in moist, heavy clay soils.

(9) Soil characteristics such as high water saturation, soil cements, clay content and organic matter content will negatively impact results of surface flux chamber measurements by restricting the rate of contaminant flux to the chamber.

(10) Humidity can affect the collection efficiency of the adsorbent media in the sorbent samplers. Soil gas, even in the drier climates, will be at a relatively high humidity condition.

(11) It is not possible to measure the efficiency of passive-sorbent monitoring devices because the bulk volume of soil gas affected by the sorbent trap cannot be measured.

(12) Sample collection by pumping soil gas from collection cans or ground probes may disturb the equilibrium between the soil gas and the gas sorbed on soil particles. This may cause dilution and/or contamination of the sample by ambient air.

(13) High background concentrations may interfere with obtaining accurate measurements when sampling with sorbents.

c. Field Equipment. A portable gas chromatograph with a photoionization detector (PID) is sensitive to benzene, toluene, ethylbenzene, and xylenes (BTEX) and decreasingly sensitive to nonaromatic hydrocarbons (octane, etc.) and chlorinated hydrocarbons. The gas chromatograph may also be equipped with a flame ionization detector (FID), which is also sensitive to hydrocarbons. The user should be aware of the advantages and disadvantages of each type of detector. Each type of detector has limitations related to the environment. The FID is sensitive to severe changes in temperature, and the PID will not function under conditions of high humidity.

d. Procedure for Conducting a Soil-Gas Survey with a Ground Probe. Use these instructions as a general guide in conducting a soil-gas survey using a ground probe near an UST.

(1) Site calibration for a portable gas chromatograph. Ideally, use commercially available vapor standards (low pressure, bottled, standard calibration gas) for instrument calibration. Inject the gas standard into the instrument with a gas-tight syringe. (If commercial gas standards are not available, vapor standards may be prepared in Tedlar bags filled with ultra-pure air. Inject the analyte of interest into the Tedlar bags from vapor obtained with a gas-tight syringe from the headspace above a neat [pure, 100 percent] standard stored in a 40 mL VOA vial with a septum cap. Prepare a new calibration standard daily. It is generally preferable to use commercially available calibration standard gases.)

More than one analyte may be of interest for the gas survey. Any compound that may have been stored in the UST (e.g., gasoline or other volatile fuels; organic solvents such as dichloroethane, trichloroethane, benzene, toluene, xylene, methylene chloride, acetone; etc.) may be used to calibrate the instrument so that quantitative results are obtained for that analyte.

(2) Typically, a hydraulic mechanism is used to drive and withdraw sampling probes 1.5 to 3 m (5 to 10 feet) long. In unusually hard soil, a hydraulic hammer may also be used. These probes are typically fitted with detachable drive tips (see Figure 5-1).

(3) Extract gas through the probe via a vacuum pump connected to the tubing. Five sample probe volumes should be extracted prior to sampling.

(4) Remove a gas sample with the gas-tight syringe inserted into the flexible tubing between the pump and the probe.

(5) Inject the gas sample into the gas chromatograph.

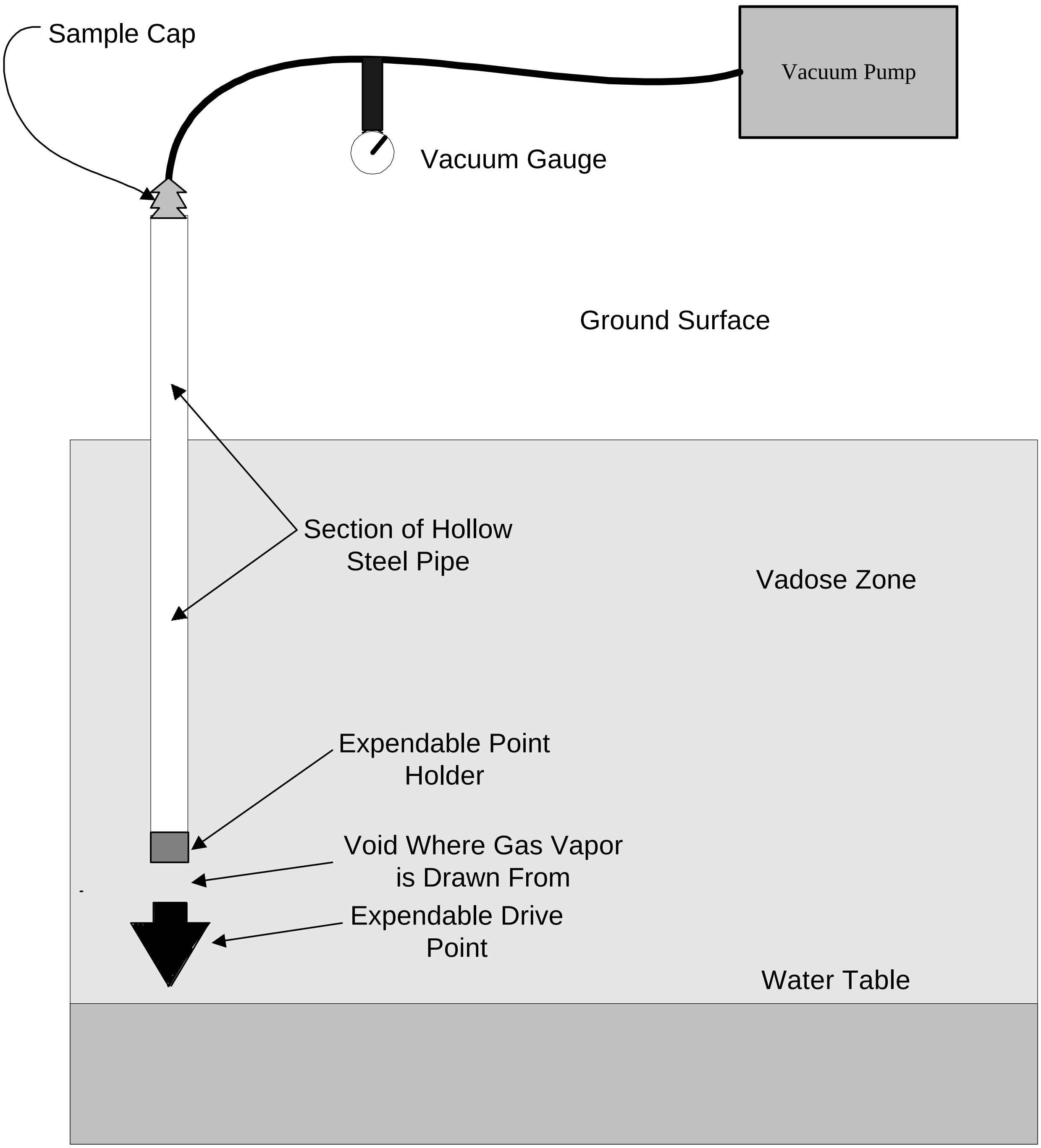

Figure 5-1 Typical Soil-Gas Apparatus

(6) Record the results in the field notebook. Note all identifiable chemicals along with the concentration of each. Also note significant unidentifiable peaks from each chromatogram. Save the chromatograms as part of the field documentation.

e. Decontamination. Dedicated sampling probes may be used in lieu of field decontamination during the soil-gas survey. These probes may then be cleaned (as described in Chapter 9) after the sampling event but before leaving the site.

If dedicated probes are not used, the following decontamination procedure should be followed.

(1) Decontaminate the probe between sample holes by removing visible soil.

(2) Do not clean with water or any liquid because this will have an effect on the gas chromatograph.

(3) Draw ambient air blanks through the probe and analyze by gas chromatography to establish that cross-contamination is not occurring.

(4) Another method that may be used for decontamination is baking the volatiles off the probe using a portable heater.

5-3. <u>Borehole Drilling/Soil Sampling.</u> Soil borings and monitoring wells are the primary means of assessing the extent of contamination from any hydrocarbon phase. Borehole drilling is a method for collecting subsurface soil samples and for subsequent well installation (discussed below). Boreholes are completed to determine the nature and extent of contamination at an UST site.

a. Methods. It is important to recognize that, while the primary focus on drilling boreholes is for soil sample collection, borings are also required for in-situ testing of subsurface materials and groundwater. Table 5-1 presents types of drilling methods.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Direct-Push	Advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the above ground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata.	30 (100)	Avoids use of drilling fluids and lubricants during drilling. Equipment highly mobile. Disturbance of geochemical conditions during installation is minimized. Drilling and well screen installation is fast, considerably less labor intensive. Does not produce drill cuttings, reduction of IDW.	Limited to fairly soft materials such as clay, silt, sand, and gravel. Compact, gravelly materials may be hard to penetrate. Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated. The small diameter drive pipe generally precludes conventional borehole geophysical logging. The drive points yield relatively low rates of water.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Auger, Hollow- and Solid-Stem	Successive 1.5-m (5-ft) flights of spiral-shaped drill stem are rotated into the ground to create a hole. Cuttings are brought to the surface by the turning action of the auger.	45 (150)	Fairly inexpensive. Fairly simple and moderately fast operation. Small rigs can get to difficult-to-reach areas. Quick setup time. Can quickly construct shallow wells in firm, nonclayey materials. No drilling fluid or lubricants required. Use of hollow-stem augers greatly facilitates collection of split-spoon samples, and continuous sampling is possible. Small-diameter wells can be built inside hollow-stem flights when geologic materials are cavey.	Depth of penetration limited, especially in cavey materials. Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles or boulders. Log of well is difficult to interpret without collection of split spoons due to the lag time for cuttings to reach ground surface. Soil samples returned by auger flight are disturbed making it difficult to determine the precise depth from which the sample came. Vertical leakage of water through borehole during drilling is likely to occur. Solid-stem limited to fine-grained, unconsolidated materials that will not collapse when unsupported. Borehole wall can be smeared by previously-drilled clay. With hollow-stem flights, heaving materials can present a problem. May need to add water down auger to control heaving or wash materials from auger before completing well.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Jetting	Washing action of water forced out of the bottom of the drill rod clears hole to allow penetration. Cuttings brought to surface by water flowing up the outside of the drill rod.	15 (50)	Relatively fast and inexpensive. Driller often not needed for shallow holes. In firm, noncavey deposits where hole will stand open, well construction fairly simple. Minimal equipment required. Equipment highly mobile.	Somewhat slow with increasing depth. Limited to drilling relatively shallow depth, small diameter boreholes. Extremely difficult to use in very coarse materials, i.e., cobbles and boulders. Large quantities of water required during drilling process. A water supply is needed that is under enough pressure to penetrate the geologic materials present. Use of water can affect groundwater quality in aquifer. Difficult-to-interpret sequence of geologic materials from cuttings. Presence of gravel or larger materials can limit drilling. Borehole can collapse before setting monitoring well if borehole uncased.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Cable-tool (percussion)	Hole created by dropping a heavy "string" of drill tools into well bore, crushing materials at bottom. Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 150 mm (6 inches) in diameter is usually made.	300+ (1,000 +)	Can be used in rock formations as well as unconsolidated formations. Can drill through cobbles and boulders and highly cavernous or fractured rock. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of hole minimizes cross-contamination by vertical leakage of formation waters and maintains borehole stability. Recovery of borehole fluid samples excellent throughout the entire depth of the borehole. Excellent method for detecting thin water-bearing zones. Excellent method for estimating yield of water-bearing zones. Excellent method for drilling in soil and rock where lost circulation of drilling fluid is possible. Core samples can be easily obtained. Excellent for development of a well.	The potential for cross-contaminated samples is very high. Decontamination can be difficult. Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Cannot run some geophysical logs due to presence of drive pipe. Relatively slow drilling method. Heavier wall, larger diameter casing than that used for other drilling methods normally used. Temporary casing can cause problems with emplacement of effective filter pack and grout seal. Heaving of unconsolidated sediment into bottom of casing can be a problem.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Mud Rotary	Rotating bit breaks formation; cuttings are brought to the surface by a circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall. Cuttings are removed by settling in a "mud pit" at the ground surface and the mud is circulated back down the drill stem.	1,500+ (5,000 +)	Drilling is fairly quick in all types of geologic materials, hard and soft. Borehole will stay open from formation of a mud wall on sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction. Geologic cores can be collected. Can use casing-advancement drilling method. Borehole can readily be gravel packed and grouted. Virtually unlimited depths possible.	Expensive, requires experienced driller and fair amount of peripheral equipment. Completed well may be difficult to develop, especially small diameter wells, because of mud or filtercake on wall of borehole. Lubricants used during drilling can contaminate the borehole fluid and soil/rock samples. Geologic logging by visual inspection of cuttings is fair due to presence of drilling mud. Thus beds of sand, gravel, or clay may be missed. Location of water-bearing zones during drilling can be difficult to detect. Drilling fluid circulation is often lost or difficult to maintain in fractured rock, root zones, or in gravels and cobbles. Difficult drilling in boulders and cobbles. Presence of drilling mud can contaminate water samples, especially the organic, biodegradable muds. Overburden casing usually required. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Reverse Rotary	Similar to hydraulic rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method. Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	1500+ (5,000 +)	Drilling readily accomplished in soils and most hard rock. Drilling is relatively fast and for drilling large diameter boreholes. Borehole is accessible for geophysical logging prior to installation of well. Creates a very "clean" hole, not dirtied with drilling mud. Large diameter of borehole permits relatively easy installation of monitoring well. Can be used in all geologic formations. Very deep penetrations possible. Split-spoon sampling possible.	Drilling through cobbles and boulders may be difficult. Use of drilling fluids, polymeric additives, and lubricants can affect the borehole chemistry. A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered. Expensive – experienced driller and much peripheral equipment required. Hole diameters are usually large, commonly 450 mm (18 inches) or greater. Cross-contamination from circulating water likely. Geologic samples brought to surface are generally poor; circulating water will "wash" finer materials from sample.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Air Rotary	Very similar to hydraulic rotary, the main difference is that air is used as the primary drilling fluid as opposed to mud or water.	1,500+ (5,000 +)	Can be used in all geologic formations; most successful in highly fractured environments. Useful at most any depth. Drilling in rock and soil is relatively fast. Can use casing-advancement method. Drilling mud or water not required. Borehole is accessible for geophysical logging prior to monitoring well installation. Well development relatively easy.	Relatively expensive. Cross-contamination from vertical communication possible. Air will be mixed with the water in the hole and blown from the hole, potentially creating unwanted reactions with contaminants; may affect "representative" samples. Air, cuttings and water blown from the hole can pose a hazard to crew and surrounding environment if toxic compounds encountered. Compressor discharge air may contain hydrocarbons. Organic foam additives to aid cuttings' removal may contaminate samples. Overburden casing usually required.
Sonic (vibra-tory)	Employs the use of high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rock.	150 (500)	Can obtain large diameter, continuous and relatively undisturbed cores of almost any soil material without the use of drilling fluids. Can drill through boulders, wood, concrete, and other construction debris. Can drill and sample most softer rock with high percentage of core recovery. Drilling is faster than most other methods. Reduction of IDW.	Rock drilling requires the addition of water or air or both to remove drill cuttings. Extraction of casing can cause smearing of borehole wall with silt or clay. Extraction of casing can damage well screen. Equipment is not readily available and is expensive.

TABLE 5-1

DRILLING METHODS

Method	Drilling Principle	Depth Limit meters (Ft.)	Advantages	Disadvantages
Air-Percussion Rotary or Down-the-Hole-Hammer	Air rotary with a reciprocating hammer connected to the bit to fracture rock.	600 (2,000)	Very fast penetrations. Useful in all geologic formations. Only small amounts of water needed for dust and bit temperature control. Cross-contamination potential can be reduced by driving casing. Can use casing-advancement method. Well development relatively easy.	Relatively expensive. As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility. Overburden casing usually required. Vertical mixing of water and air creates cross-contamination potential. Hazard posed to surface environment if toxic compounds encountered. DTH hammer drilling can cause hydraulic fracturing of borehole wall. The DTH hammer requires lubrication during drilling. Organic foam additives for cuttings' removal may contaminate samples.

(1) Selection of the most appropriate method or combination of methods must be dictated by the special considerations imposed by multipurpose borings. For example, although the best apparent method for well installation at a particular site may be direct air rotary with driven casing, most air rotary equipment allows sampling only by cuttings. If, in this case, soil sampling is required, pilot (or separate) borings done with equipment capable of providing adequate undisturbed samples may be necessary. In addition, if drilling is to be conducted in an area of perched or multiple aquifer systems, auger techniques should not be used because of the possibility of cross-contamination; borings must be advanced using multiple casing techniques that allow isolation of each aquifer encountered. Additional guidance on drilling methods may be found in EM 1110-1-4000 and the following ASTM Standards:

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 5781 Guide for the Use of Dual Wall Reverse-Circulation Drilling

D 5782 Guide for the Use of Direct Air Rotary Drilling

D 5783 Guide for the Use of Direct Rotary Drilling With Water-Based Drilling Fluid

D 5784 Guide for the Use of Hollow-Stem Augers

D 5872 Guide for the Use of Casing Advancement Drilling Methods

D 5875 Guide for the Use of Cable-Tool Drilling and Sampling Methods

D 5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods

D 6286 Guide for Selection of Drilling Methods for Environmental Site Characterization

(2) The planning, selection, and implementation of any drilling program requires careful consideration by qualified, experienced

personnel. At a minimum, the following general steps are required:

(a) Review existing site, area, and regional subsurface; geologic; and hydrogeologic information including physical and chemical characteristics.

(b) Develop project DQOs and a SAP. See EM 200-1-2 and EM 200-1-3 for additional guidance.

(c) Develop a site-specific safety and health program.

(d) Define the purpose of the drilling and sampling, select drilling methods and general site layout, and prepare and execute the drilling contract.

(e) Field implementation and decontamination includes continuous inspection by qualified, experienced personnel.

(3) Selection and implementation of soil drilling and sampling methods requires that specific consideration be given to the following issues:

(a) Prevention of contamination migration.

(b) Maintenance of sample integrity.

(c) Minimization of disruption of existing conditions.

(d) Minimization of long-term impacts.

b. Equipment. Guidance on sampling equipment may be found in EM 200-1-3 and EM 1110-1-1906. Additional guidance may be found in ASTM D 6169. Hollow stem auger drilling is frequently used and may include the following:

(1) Hollow-stem auger and drill rig.

(2) Sampling tubes. Sampling systems may consist of either of the following:

(a) Continuous sampling tube systems consisting of 1.5m (5-foot) long split or solid sampling tubes. Tubes can be used with or without liners of various metallic and nonmetallic materials. Continuous samplers advance with the auger flights.

(b) Split-spoon sampling consisting of 0.5m (18-inch) long split spoons with basket-retainer shoe. Split spoons are driven into the soil ahead of the auger using a drive hammer.

(3) Stainless steel knives, spoons, and bowls.

(4) Sample containers (see Chapter 8).

(5) Ice.

(6) Shipping coolers and supplies.

(7) Decontamination equipment (see Chapter 9).

(8) Logbook.

c. Procedures.

(1) Obtain any federal, state, or local permits required for constructing wells or clearing the site for work or access. Contact regulatory agencies to obtain their regulations concerning submission of boring/well logs and samples.

(2) At each borehole the geologist must maintain a log that contains at a minimum the following information:

(a) Name of the project and site.

(b) Hole number.

(c) Location of the boring.

(d) Type of drill rig and method of drilling.

(e) Size and type of bit used.

(f) Depth of each change of stratum.

(g) Thickness of each stratum.

(h) Identification of the material composing each stratum according to the Unified Soil Classification System, or standard rock nomenclature, as necessary.

(i) Depth interval from which each formation sample was taken.

(j) Hole diameter and depth at which hole diameter (bit size) changes.

(k) Depth at which groundwater is first encountered.

(l) Depth to the static water level and changes in static water level with hole depth.

(m) Total depth of hole.

(n) Depth or location of any loss of drill water circulation, loss of tools or equipment, and any other problems encountered.

(o) Location of any fractures, joints, faults, cavities, or weathered zones.

(p) Reference elevation for all depth measurements.

(q) Name of driller and geologist.

(r) Standard Penetration Test blow counts, if applicable.

(s) Date(s) of drilling, including depths where work shifts begin and end.

(3) To take a subsurface soil sample (after the sampler is retrieved from the borehole), follow these steps:

(a) Set up decontamination, sampling preparation, and support areas at borehole location.

(b) Decontaminate all equipment, samplers, and tools that will come in contact with sample media (see Chapter 9 for decontamination procedures). Record decontamination process in logbook.

(c) Inform driller of sample interval(s) for borehole and oversee sampling process.

(d) Prepare and label all sample containers. If any volatiles are analytes, have the volatiles containers available first. Label containers with location, depth, analyte, date, and time of sampling.

(e) Have the driller prepare the sampler for opening, but do not allow the driller to completely open the sampler.

(f) With the sampler lying on a clean sheet of plastic, the onsite geologist should open the sampler slowly. As the sampler is being opened, the surface of the core should be "sniffed" with a PID/FID. Position the probe of the instrument approximately 25 mm (one inch) from the sample. Record instrument readings in the logbook. If the PID/FID reading is above background, a soil sample should be collected from the anomalous interval. Consult with the site manager to determine whether to submit for chemical analyses.

(g) For those locations in which VOCs are analytes, VOC samples must be collected immediately after the sampler is opened. Using a sampling knife, cut off solid piece(s) (nominal 25 mm [one inch] in size) of sample and place piece(s) into the container. Immediately close container and place on ice. The container must not have any headspace if the sample is to be analyzed for VOCs.

(h) Log the core, recording percent recovery, color, texture, clay, sand, gravel content, and other notable characteristics in the logbook.

(i) After logging, transfer sample to mixing bowl and thoroughly homogenate the sample.

(j) Fill remaining sample jars.

(k) Prepare necessary QA/QC samples.

(l) Log all samples in field notebook; Include borehole ID sample number, analyte(s), date, time, and collector signatures.

(m) Pack samples for shipment, prepare chain-of-custody records and shipping documentation (see Chapter 8).

(n) Ship samples as specified in Chapter 8.

(4) If the borehole is to be used for a well installation, follow procedures outlined in Paragraph 5-4 below, otherwise grout the borehole. The grout mixture should be composed of Portland cement mixed to a ratio of 27 liters (7 gallons) of water per sack of cement with a 3-percent bentonite powder additive. Grout must be pumped into the borehole via a tremie pipe.

5-4. Well Installation.

a. Purpose. The purpose of a monitoring well is to provide an access point for measuring groundwater levels and to collect groundwater samples that accurately represent in-situ groundwater conditions at the specific point of sampling. Consult EM 1110-1-4000 for guidance on monitoring well installation.

To procure accurate samples, follow these criteria:

(1) Construct the well with minimum disturbance to the formation.

(2) Construct the well of materials that are compatible with the anticipated geochemical and chemical environment.

(3) Complete the well properly in the desired zone.

(4) Seal the well adequately with materials that will not interfere with the collection of representative water-quality samples.

(5) Develop the well sufficiently to remove any additives associated with drilling and provide unobstructed flow through the well.

b. Groundwater Sampling. Prior to well sampling, the task manager/field team leader is responsible for collecting and reviewing information about the well. This information should include: well construction methods and materials, well logs, well size, well depth, screen interval(s), and purpose of well (monitoring, water supply, etc.). This information should accompany the field crew during sampling. The following procedures should be followed during a groundwater sampling event:

(1) Set up decontamination, sample preparation, and support area at wellhead. (This may be at the rear of a truck/van.)

(2) Decontaminate all equipment/instruments that will be placed into well casing or come in contact with water samples. Record decontamination process in logbook.

(3) Review well log for construction, size, and well depth. Record information in logbook. *Do not measure the total depth of the well prior to sampling*. Measuring to the bottom of the well casing may cause re-suspension of settled solids from the formation materials and require longer purging times for turbidity equilibration. Measure the well depth after sampling is complete.

(4) Using water-level probe, determine water level (ASTM D 4750). Record in logbook.

(5) Calculate purge volume. ***NOTE***: USACE well-purging procedures specify including the volume of water in the filter (sand) pack in purge-volume calculations. To prevent purging an unnecessarily large volume of water, calculate height of water column using water level and construction data. Also using construction data, calculate volume of one casing plus filter-pack volume (i.e., one purge volume) using the following formula:

Volume (gallons) = Br^2h (cu. ft). X 7.48 (gallons/cu. ft).

r = radius in feet (of either auger borehole or well casing as described below).
h = height of water column in feet.

Because the water contained in the sand pack will be used in the calculations, follow these steps:

(a) Calculate the total volume of the saturated portion of the borehole. Use the radius of the overall borehole (sand pack plus well casing) for the calculation. This is Volume A.

(b) Calculate the total volume of the well casing. Use the radius of the well casing for the calculation. This is Volume B.

(c) Determine the volume of the saturated portion of the sand (filter) pack. This is done by subtracting Volume B from A and multiplying the result by a porosity factor of 0.35. This will be Volume C, the sand-pack volume, as shown here:

(Volume A – Volume B).35 = Volume C (sand-pack volume)

(d) Add Volumes B and C to produce volume of water for one filter (sand) pack and well casing. That is:

Volume B + Volume C = Volume D, (filter-pack and casing volume)

Record calculations and the purge volume (Volume D) in logbook.

(6) The well should be purged of at least three casing and sand (filter) pack volumes or until pH, temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity are each at equilibrium. Equilibrium is established when three successive readings are within:

- ±0.2 pH units.
- ±1 degree Celsius for temperature.
- ±3 percent for specific conductance.
- ±10mV for oxidation-reduction potential (ORP).
- ±10 percent for DO.
- ±10 percent turbidity.

Equilibrium will be established by three consecutive readings, where one casing volume is pumped between each reading. Multiply the filter-pack and casing volume by three to produce the minimum purge volume. If well is purged dry before three purge volumes, allow well to recover and then sample. See EM 200-1-3 for more guidance on well purging.

(7) Begin purging well using either bailer, submersible pump, or in-place pump.

(8) Collect all purge water in 55-gallon drums until the disposal method can be determined based on water quality results. ***NOTE***: In some instances, purging rates must be kept below 500 mL/min to avoid over pumping or pumping the well to dryness. Ideally, wells should never be pumped to dryness.

(9) Initiate sampling after purging has been completed. Label all sample containers with well ID, date, and time of sampling, analytes, and preservative. See Table 8-3 for sample bottle requirements. If bioremediation is a potential treatment option, samples should be collected for testing for nitrates, sulfates, ferrous iron, and methane.

(10) Collect sample with a freshly decontaminated bailer. Lower bailer carefully into well to prevent aeration of well.

(11) Fill VOA containers first (add two drops HCl acid preservative to containers prior to filling). Overfill container, put on cap, and invert container to check for bubbles. If bubbles are present, discard sample and refill. Place samples on ice.

(12) Fill other organic analyte bottles next. Do not completely fill the container. Leave approximately 10-percent volume as head space. Mark the volume on the container with a grease pen. Preserve as specified in preservation table. Place samples on ice.

(13) Fill remaining inorganic analyte containers.

(14) Log all samples in field logbook; include well number, identifier, analyte(s), date, time, and collector signatures. Record time of purge, purge volume, and water quality parameters in logbook.

(15) Pack samples for shipment; prepare chain-of-custody records and shipping documentation.

(16) Ship samples as specified in Chapter 8.

c. Free Product. Properly installed and constructed monitoring wells can be used both to delineate the extent of free product and monitor temporal changes in free product accumulations. However, it is also important to realize that monitoring wells are subject to significant limitations in their ability to provide accurate measurements of the thickness of free product in the surrounding soil. Free product can accumulate in a well only if the well is open (i.e., screened) across the zone of free product. Within a well with a properly positioned screen, the thickness of free product typically fluctuates in response to changes in water table elevation. Where wells are initially installed with short screens (1.5 m [5 ft] or less), changes in the water table elevation may result in a dry well (declining water table) or in a well that is screened below the zone of free product (rising water table). Even in properly constructed wells, the absence of free product may not necessarily indicate that petroleum hydrocarbons are not present in the soil. Similarly to the observation that water may take days or weeks to enter some monitoring wells constructed in clayey soil, free product may not initially appear in monitoring wells. Such a condition indicates that the relative permeability with respect to free product is very low; hence the mobility of the free product is also low. This may also result in a lower calculated volume of free product.

(1) Record the thickness of free product, if encountered. Three methods are commonly used to measure free product thickness in a well: steel tape and paste, interface probes, and bailers.

The pastes used with the steel tape are sensitive to hydrocarbons and water. Commercially available interface probes sense the presence of both oil and water. The first two methods are accurate to within about 3 mm (0.01 ft) and are convenient for determining the elevation of the air/free product and oil/water interfaces. Whenever possible, measurements should be taken using either steel tape and paste or an interface probe. A bailer is a transparent cylinder with a check valve at its base. The bailer methods can significantly under- or over-estimate the thickness of free product in the well and **should not** be used for determining the elevations of air/free product and free product/water interfaces. Disposable bailers, which are commonly dedicated to monitoring wells containing free product, typically collect an unrealistically small product thickness because of the small size of the intake holes. The use of bailers should be limited to verification of the presence of free product in a well or collection of a small sample of it. Bailers can be used to remove liquids from monitoring wells during baildown tests that are designed to determine the rate of free product recovery into wells. For more information on free product measurement and recovery see EPA/510/R-96/001.

5-5. Aquifer Testing. After completion and development of all monitoring wells, perform slug tests at each well to provide data to contribute to the hydrogeologic characterization of the site. Slug tests provide data to approximate hydraulic conductivity and transmissivity of the aquifer. The slug test is a useful tool for estimating the areal variability of these parameters within a given unit and does not require that any water be discharged from the tested well. Also, the test does not artificially induce contaminant flow and can be performed on wells within known or suspected groundwater contamination plumes. Further information on aquifer testing may be found in *EPA Groundwater Issue on Suggested Operating Procedures for Aquifer Pumping Tests*, EPA/540/S-93/503. Guidance for measuring well discharge may be found in ASTM D 5737.

a. Procedure. To perform a slug test, a solid slug is introduced into the well and changing water levels are measured with a transducer. Water level and elapsed-time data can be recorded with a data logger and pressure transducer. Both "rising heads" and "falling heads" are recorded. Additional guidance on conducting a slug test may be found in EPA/540/P-91/007 and ASTM D 4044.

b. Data. Data from the slug tests can be input from the strip logs into a computer spreadsheet for review. After these data are checked for accuracy, the data file can be transferred into a commercially available program that calculates hydraulic conductivity (m/day [gal/day/ft^2]) and transmissivity (m^2/day [gals/day/ft]) for the aquifer.

5-6. <u>Soil Testing</u>. To determine an appropriate corrective action for contaminated soil and/or groundwater, site-specific information relating to the hydrologic and geologic characteristics of the site, as well as soil chemistry, is needed. These characteristics include depth to groundwater, soil temperature, moisture content, soil water field capacity in accordance with ASTM D-2325, or ASTM D-3152, particle-size distribution, bulk density, saturated and unsaturated hydraulic conductivity, dissolved oxygen, carbon dioxide, total organic carbon, and total volatile hydrocarbons.

An example of the importance of these parameters is: a soil's hydraulic conductivity directly affects a contaminant's mobility, while soil air conductivity affects the mobility of the contaminant vapors. Air and hydraulic conductivity varies from formation to formation in much the same way, with formations of low hydraulic conductivity generally having low air conductivity as well.

The procedures for collecting field samples for soil parameters are covered extensively in many other publications and are not discussed in this manual. Soil characterization data needs for different remedial technologies can be found in EM 200-1-2.

5-7. Survey. When there is a release from an underground storage tank, the horizontal and vertical extent of the contamination must be determined. To make an accurate determination of contamination extent, verify borehole and monitoring well locations as well as the elevations of the monitoring wells. Designers use this information to develop a site-specific groundwater contour map, for calculating the groundwater gradient and flow rate, and a three-dimensional model of the soil contamination. Coordinates and elevations should be established for each well and boring location to a minimum of third order survey. Elevations should be provided for each well casing to the closest 5 mm (0.01 foot).

5-8. Waste Disposal.

a. Disposal of Drill Cuttings. Cuttings must be tested using a PID/FID to help determine contaminant status. Potentially contaminated cuttings must be handled as described in "b. Collection and Testing of Potentially Hazardous Materials" (below). Potentially contaminated drill cuttings and/or vapors are defined as those substances with PID/FID readings in excess of 5 ppm above background levels. This assumes that the tanks being pulled are POL tanks and that the primary contamination is from volatile contaminants. If this is not the case, analytical results of actual soil samples must be used. The implementing agency should provide guidance values for soil disposal. Additional guidance may be found in EPA/540/G-91/009.

b. Collection and Testing of Potentially Hazardous Materials. Materials generated during field activities must be placed in properly labeled drums that are Department of Transportation (DOT)-approved for transport of hazardous materials Follow these guidelines:

(1) Segregate all materials in separate drums (i.e., soil, water, tyvek, and other similar materials).

(2) Secure drums at a designated staging area on wooden pallets, pending receipt of analytical results.

(3) Label all drums adequately prior to moving them to the staging area. Label drums in a permanent, waterproof manner in accordance with the IA requirements. Drums must not be labeled on the top. At a minimum, label drums as to type of material contained, site number, and location boring numbers.

The eventual disposal of the contents of these drums is determined by the results of the associated analytical tests for the project. Local regulations may preclude the use of drill cuttings as backfill. Check with the local IA to determine if non-contaminated drill cuttings need to be containerized and disposed of offsite.